Phase I Project Summary

Firm: Physical Sciences Inc. **Contract Number:** NNX11CI11P
Project Title: Silicon Whisker and Carbon Nanofiber Composite Anode

Identification and Significance of Innovation: During this Phase I program, PSI and UConn successfully demonstrated the feasibility of using N-functionalized mesoporous graphitic carbon materials as catalyst supports. These supports demonstrate improved corrosion resistance as compared to conventional support materials, a necessary criteria for utilization in NASA's fuel cells operating on pure oxygen. During this program, PSI and UConn demonstrated that the resulting catalyst/supports provide improved stability, mass activity, and Pt dispersion. Accelerated testing in hydrogen and oxygen at 1 and 1.2V demonstrated <2% reduction in the low current performance over 19 total hours of oxidation with improved performance observed at currents >0.3A/cm^2. Further, the performance fade was all observed after holding at 1V for 4 hours, with no fade after holding at 1.2V for 15 hours. This performance level and the intrinsic features of the electrocatalyst will result in fuel cells with reduced catalyst loadings/kW and therefore lower initial and lifetime costs. Initial validation in the laboratory environment represents advancement of this technology to TRL 4.

Technical Objectives and Work Plan:

1. Demonstrate tunable nitrogen content of 0 to 10atomic % for the graphitic carbon.
2. Demonstrate surface area for the functionalized graphite of >500m^2/g.
3. On accelerated testing of the N-functionalized graphite, demonstrate an 80% reduction in the corrosion current as compared to standard carbon supports.
4. For a fuel cell constructed using the functionalized graphite, demonstrate that as compared to a fuel cell using commercially available supports upon steady state operation the open circuit voltage, mass activity, and current is reduced by less than 5%.
5. On accelerated lifetime testing of the functionalized support demonstrate that:
   - After a 200hr hold at 1.2V the potential at 1.5A/cm^2 is reduced by less than 30mV.
   - On potential step cycling (30,000 cycles at 0.7 and 0.9V for 30 seconds each) the cell potential at 0.8A/cm^2 is reduced by less than 30mV. Additionally, demonstrate that the loss in mass activity is <60%.
6. PSI and UConn will work together to develop a plan for scaling the production of nitrogen functionalized carbon to >25g per batch.

Tasks: reporting; synthesis and electrochemical and physical characterization of bare and platinized supports; fuel cell construction; steady state and accelerated life testing; scale-up.

Technical Accomplishments: During this Phase I program:

- UCONN has demonstrated an ability to tailor the nitrogen content in their mesoporous supports and characterized the impact of pyrolysis temperature on the surface area and activity of the platinized materials.
  - Support materials were prepared that exceeded the targeted values for C/N content, corrosion current inhibition, and surface area.
  - Improved mass activity was demonstrated as compared to the baseline commercial catalyst support.
- Demonstrated that the UCONN catalyst/support delivers similar performance in a fuel cell as platinized Vulcan supports.
- Improved stability was demonstrated at UCONN and PSI upon transitioning to samples prepared at higher temperatures.
- Demonstrated thermal treatment procedure for the Pt/support materials that results in improved stability.
- Demonstrated less than 2% performance fade upon fuel cell operation at 1.2V for 15 hours.
- Thermally digestible template identified that has been demonstrated to produce high surface area (~1000m^2/g) porous carbon materials while retaining N found in the template.
- PSI delivered two 25cm^2 MEAs incorporating the most stable UConn electrocatalyst material in the cathode electrode.

NASA Application(s): The proposed technology could be utilized in all primary and regenerative proton exchange membrane fuel cell systems (PEMFCs). Incorporation in NASA PEMFC systems would enhance the durability of the electrocatalyst-support system extending the system lifetime. Further, increased interaction with the catalyst may allow for reduced catalyst loadings, reducing total system cost.

Non-NASA Commercial Application(s): The initial market for the proposed technology is military applications requiring a stable, long-life power source. Military applications of fuel cells range from portable power sources for the foot soldier to undersea vehicle power supplies. The Army and the Defense Advanced Research Projects Agency have been funding the development of proton exchange membrane fuel cell systems for individual soldiers in the field. Applications for these fuel cell power sources include electronic equipment, micro-climate cooling, digital battlefield sensors, and battery charging.

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